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Application of 3D full waveform inversion on real marine data sets

Rene-Edouard Plessix
Shell International E&P, Rijswijk, The Netherlands (reneedouard.plessix@shell.com)

Full waveform inversion (FWI) was proposed more than 25 years. Over the last ten years, several real 2D examples have been published showing the potential and the difficulties of this approach. The application of acoustic FWI to sizeable real 3D data sets became possible a few year ago thanks to the increase of computer power. The developments in seismic acquisition are also an enabler to FWI that works best with wide aperture data sets and low frequencies. In this way, the Ocean Bottom Seismometer (OBS) or Ocean Bottom Cable (OBC) data sets are well suited since they often contain long offsets, wide azimuth and low frequencies. In this presentation, I will describe the results we obtained by inverting a deep-water OBS data set from the Gulf of Mexico. The data set contains offsets up to 17 km. A classic multiscale FWI was applied starting at 2 Hz. FWI helps to reveal shallow gas accumulations that were difficult to capture with classic reflection traveltime inversion. The presence of these gas accumulations was also supported by a visco-acoustic FWI and an inversion for the quality factor. This result illustrates the power of FWI to image the shallow structures where diving waves propagate. Detecting these shallow velocity anomalies is not only important for imaging but also for hazard analysis, for instance, during a well planning.
Analysis of the isotropic FWI results showed that some of the reflected energy was not correctly interpreted, since after pre-stack migration the common image gathers were not flat. In fact, FWI tries to interpret both reflected and refracted energy. Since the sediments in the Gulf of Mexico are anisotropic, the reflected and refracted waves may travel with a different velocity. We then carried out a VTI (Vertical Transversely Isotropic) FWI with a fixed ratio between the NMO (Normal MoveOut) velocity and the horizontal velocity. This ratio was found by traveltime inversion and is spatially varying. Migrating with the velocity found by VTI FWI led to a better image even for the sediments beneath the salt at 6 km depth. This improvement at those depths however strongly depends on the accuracy of the initial model since FWI works in a (non-linear) migration mode at that depth with this acquisition. Depending on the permission to publish, I may also discuss some results obtained with a more traditional narrow azimuth streamer data sets.